Tin target modelling for 13.5 nm LPP EUVL

Maximising Conversion Efficiency (CE)

Maximising the CE of radiation to laser energy is paramount to producing an optimum next generation lithography light source at 13.5 nm. Laser-produced plasma emission from Sn IX–Sn XIV ions is one proposed solution [1, 2]. The effect of target geometry for a Nd:YAG laser pulse incident on solid tin using a 2-D RMHD code is analyzed to determine optimum conditions for maximum brightness. Previous studies have shown a 1.5% CE on planar and spherical bulk targets [3]. Here, we obtained a 54% increase in calculated CE using a 1-μm thick ribbon compared to a bulk target.

Multi-element slab tin target

Z* is an implicit, 2-D RMHD code, which solves ionisation kinetics self-consistently with radiation transfer [4]. A multi-element grid was used with 64 (8 x 8) different target dimensions ranging from 140 to 4314 μm in width and 1 to 1000 μm in depth. The reference laser was a 1.064-μm Nd:YAG with energy 2 J, duration 8 ns and a focussed spot size diameter of 270 μm, giving a power density of 1.4 x 10^{11} W/cm^2, already shown in calculations to maximize the fraction of Sn^{10+} ions for optimum 13.5-nm emission [5].

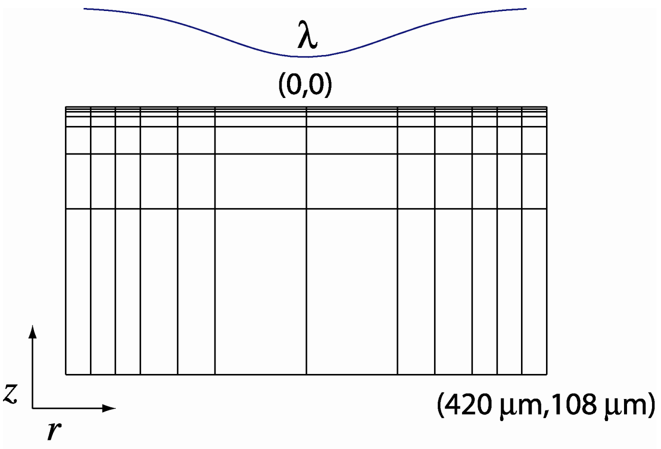

Figure 1 Z* geometry (at twice scale in z direction).

CE	r (μm)							
z (μm)	140 0.52	210 0.78	270 1.00	308 1.14	342 1.27	388 1.44	420 1.54	4314 16.0
1	**0.66**	1.28	**2.03**	2.28	**2.43**	2.43	2.42	2.43
2	0.84	1.49	2.11	2.19	1.83	1.80	1.69	1.58
4	0.87	1.53	2.13	2.16	1.81	1.79	1.68	1.58
8	0.89	1.55	2.14	2.15	1.76	1.76	1.65	1.58
16	0.90	1.55	2.10	2.09	1.73	1.72	1.60	1.58
34	0.92	1.53	2.06	1.93	1.69	1.65	1.59	1.58
108	0.90	1.50	1.91	1.74	1.60	1.59	1.59	1.58
1000	**0.73**	1.16	**1.50**	1.55	**158**	1.58	1.58	1.58

Table 1 Theoretical conversion efficiency into 2π versus target width (r) and depth (z).

Targets range from a minimum 140 μm x 1 μm to a maximum 4314 μm x 1000 μm [5], modelling a short ribbon to an infinite slab. The maximum CE was obtained for the 342 μm x 1 μm ribbon target, a 54% increase in CE to the bulk target at a 1.27 ratio of target length to laser spot size. The increased CE can be attributed to better target coupling [6], which does not excessively heat the central plasma region beyond 40 eV [3], optimum for 13.5-nm emission from tin-containing ions [1, 2], and greater lateral expansion which creates a more optically thin plasma.

Electron temperature and electron density (six cases)

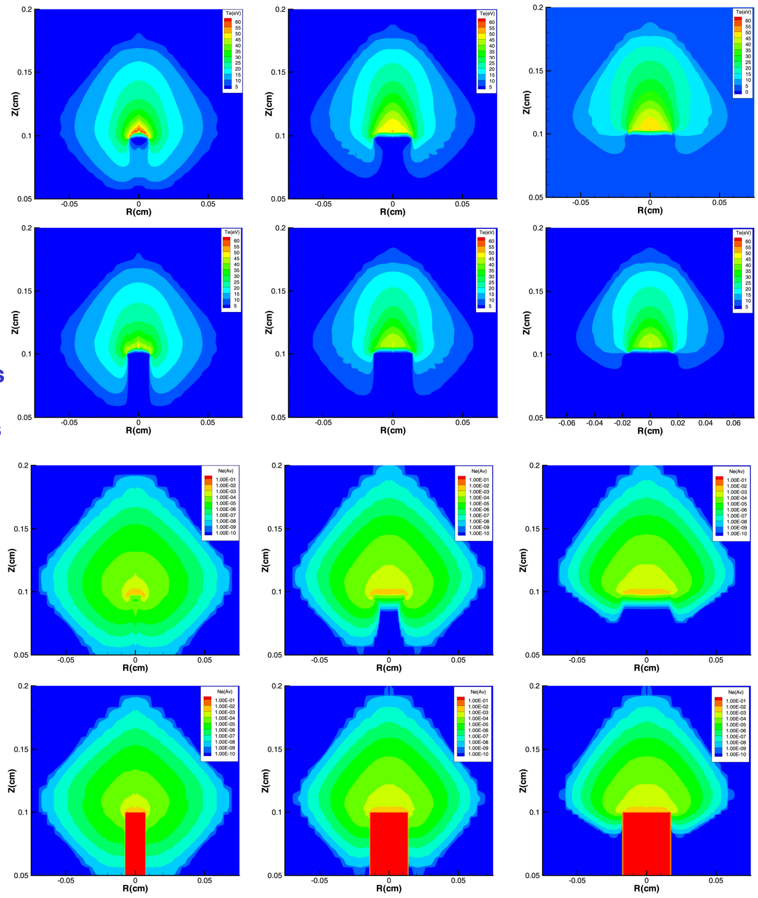

Figure 2 Electron temperature (top six) and electron density (bottom six) at the peak of the pulse: 140x1, 270x1, 342x1, 140x1000, 270x1000, 342x1000, corresponding to less than, equal, greater than the laser spot size.

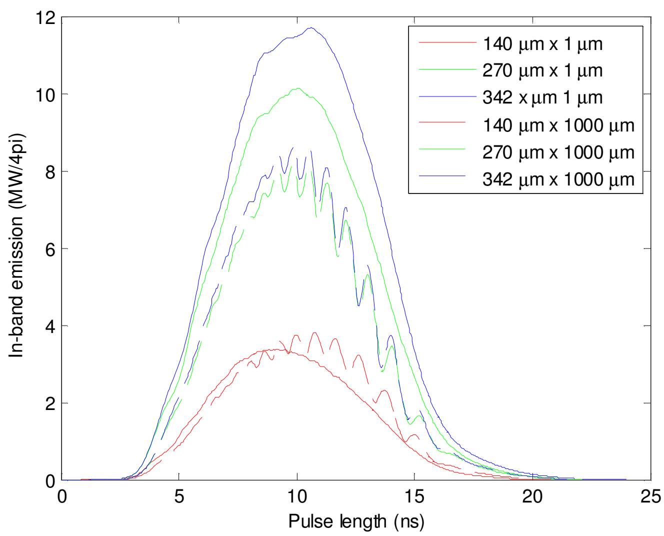

Figure 3 Emission from ribbon (solid) and bulk (dashed) targets.

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